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THE FERTILIZER INDUSTRY IN THE UAR : FACTORS DETERMINING THE CHOICE OF RAW MATERIALS AND PROCESSES

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THE FERTILIZER INDUSTRY IN THE U.A.R.

Factors Determining the Choice of Raw Materials and Processes

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Introduction

1. The prime resource of the U.A.R. is its fertile agricultural land. The land under cultivation amounts to about 6 million feddans and through perennial irrigation is the equivalent of 10.3 million feddans of crop yields. U.A.R. agriculture is dependent on relatively heavy use of fertilizer to maintain crop yields. In 1952 for example, the country consumed about 600,000 metric tons of imported nitrogen fertilizer (based on 15.5%N) in addition to about 110,000 tons locally produced. The consumption has, since then, steadily increased, e.g. in 1961 it amounted to 1,232,000 tons. Superphosphate consumption amounted to about 110,000 tons in 1952, most of which was locally produced, but in 1961 the consumption increased to about 300,000 tons.

2. The domestic fertilizer industry has grown very rapidly since the 1952 revolution. This rapid growth springs not only from a basic desire to become self-sustaining but also from a desire to increase the productivity of the land.

3. The only nitrogen fertilizer plant before 1952 was erected in Suez in 1949 with an annual production capacity of 200,000 tons of calcium nitrate (15.5%N), although the actual production was only 110,000 tons in 1952. Superphosphate was produced by

two factories, one in the Delta area (annual capacity 65,000 tons, erected 1937) and the other in the Cairo area (annual capacity 35,000 tons, erected 1948).

The First Five Year Plan

4. Early in 1957 the Ministry of Industry, submitted to the nation its first five-year plan. In this plan special attention was given to the development of the nitrogen fertilizer industry. The plan included three projects, viz.,

(a) the erection of a new plant in Aswan for the production of ammonium nitrate with an annual capacity of about 530,000 tons calcium ammonium nitrate (20.5%N) .

(b) the extension of the Suez plant from 200,000 tons to 250,000 tons/year of calcium nitrate.

(c) the erection of a new unit in the Suez plant for the production of 100,000 tons of ammonium sulphate per year (20,5%N) .

The first two projects have already started production during 1960 while the third project has just started.

5. The two superphosphate factories had been extended during 1954-1955 to bring up their annual capacities to 120,000 tons and 70,000 tons of superphosphate respectively.

The Second Five Year Plan

6. It took only three years to implement most of the projects of the first five-year plan. Hence, late in 1959 the second five-year industrial plan was drawn up and was incorporated in the first over-all five-year economic plan of the country. In this plan it was estimated that the annual fertilizer needs by 1965 would be about 2 million metric tons of nitrogenous fertilizer (15.5 percent N) and 556,000 metric tons of superphosphate (15 percent water soluble P_2O_5). Roughly 14% of the total needs would be for newly reclaimed arable land.

7. The plan therefore included projects which would satisfy completely those needs. In the choice of location for the new plants, the common factors were taken into consideration, viz., availability of suitable raw materials, transportation facilities, power, water and labour supply. Expansion of an already existing plant, whenever possible, was always preferred to the erection of a completely new one. Such a procedure not only cuts down on capital investment and plant running costs, but also saves on badly needed well trained technical personnel and skilled labour.

The total production capacity of nitrogen fertilizers by 1965 will be as shown in Table 1 (the total of 2,215,000 metric tons is based on 15.5%N). It is expected that during 1965 the newly constructed plants may not be working with full capacity and hence the actual production during that year would be around two million tons.

8. The superphosphate production will reach a total of 580,000 tons by 1965. The two existing factories will be doubled in capacity and a new plant will be erected in Asyut, Upper Egypt, with a capacity of 200,000 tons per year. This latter plant would supply the Asyut province and Upper Egypt regions south of Asyut with

their requirements of phosphatic fertilizers.

Raw Materials and Processes

A. Superphosphate

9. The rock phosphate used for the production of superphosphate is obtained from the Nile Valley Mines in the Sebaiya region 280 km north of Aswan (The ore contains 63.5 - 65.5% tricalcium phosphate). The sulphur dioxide for the manufacture of sulphuric acid has so far been obtained by the roasting of iron pyrites (imported mainly from Cyprus and Spain). However, the new plant at Asyut , as well as the extension of the Delta region plant (from 120,000 to 240,000 ton/year) will both employ elemental sulphur instead of pyrite. The use of sulphur instead of pyrite needs a lower capital investment and produces a cheaper acid.[1] Moreover, about 30,000 tons of sulphur will be produced from desulphurization of petroleum gases in a coking plant at Suez.

10. In the Delta region plant, the superphosphate is manufactured by the continuous Broad Field process to which we have introduced important modifications[2]. For example, the mixer length has been reduced so as to contain ten instead of twenty paddles, the mixer shaft speed has been increased from 100 to 500 R.P.M. and the pinion drive of the mixer shaft was replaced with a V - belt drive. As a result, the production capacity of each unit has been largely increased. The normal 5 ton/hour unit now produces 15 tons/hour and the normal 10 ton/hour unit now produces 20 tons/hour. Also the feeding device of sulphuric acid to the mixer has been modified. Conc. acid and water are now fed simultaneously to the mixer and thus the dilution and cooling systems could be dispensed with.

B. Nitrogen Fertilizers

11. The main raw material from which commercial nitrogen fertilizers are made is ammonia. The synthesis of ammonia is effected by reacting three volumes of hydrogen gas with one volume of nitrogen gas over a catalyst under pressure. Hydrogen for ammonia synthesis is commercially produced from various raw materials. Thus : -

(a) In the Nasr Fertilizer and Chemicals Co. plant at Suez, gases from a near by refinery, are reformed. These gases have the following average composition : Methane 35%; ethane 10%; ethylene 10%; propane 30%; higher hydrocarbons 15% .

(b) In the "Kima" plant at Aswan, cheap electric power is available from the Aswan Dam Hydro-electric Scheme, and therefore, hydrogen is produced by the electrolytic reduction of water.

(c) In the plant of Nasr Co. for Coke and Chemicals at Helwan

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1) Aries, R.S. and Newton R.D., Chemical Engineering Cost Estimation, Mc Graw-Hill Book Co., Inc., New York (1955) , page 9.

2) Shafik, M., The modification of Broad Field's acidulating units in Egypt, International Superphosphate Manufacturers' Association, London, September meeting 1953, paper L E 393 .

near Cairo, 360,000 cubic meters per day of coke oven gas are going to be produced (This quantity will be doubled in the second stage of production). The erection of the coking plant is now near completion. Partial oxidation of the coke oven gas will produce synthesis gas.

(d) Steam Cracking of Light Naphtha. About 120,000 metric tons per year of 70°C endpoint straightrun gasoline will result from our petroleum projects. Steam cracking of this light gasoline will produce the unsaturated hydrocarbons (to be used for the production of various petrochemicals) as well as, hydrogen, methane and ethane which will be used to produce synthesis gas for the manufacture of ammonia.

Factors Governing the Choice of Various Processes

12. The factors which governed the choice of a particular process were basically economic. Among these were the type and cost of raw material available, direct plant cost, cost of utilities, maintenance, efficiency of the particular process and hence the expected return on investment.

The following are three case studies:

(a) The "Kima" plant at Aswan. available cheap electric power could be used to produce electrolytic pure hydrogen and also could be used to produce nitrogen by air liquefaction followed by rectification.

The by-product oxygen available from both the electrolysis plant and from the air separation plant could be used to enrich the air used to oxidize the synthesised ammonia to nitrogen oxides.

(b) The Suez fertilizer plant. In this plant refinery of gases are mixed with steam and passed into a reforming furnace. This consists of a number of vertical nickel - chromium - iron alloy tubes mounted in a refractory furnace. Heat for the endothermic reaction is supplied by a number of fuel oil burners located at the bottom. Experience has shown that at the temperature of the reaction (around 1000°C), the Ni-Cr - Fe tubes corroded heavily and were a source of great trouble. It has recently been decided to replace this system by the partial oxidation process. It is estimated that the running cost per hour of the 260 ton/day ammonia plant will be diminished by about 18% of its present figure.

In the five nitric acid units erected in 1949 oxidation of the ammonia and absorption of nitrogen dioxide are both carried out under a pressure of about four atmospheres. The 6th unit erected in 1958 employed a process of oxidation under atmospheric pressure and absorption under a pressure of four atmospheres. We found this latter unit most satisfactory since it is characterised by a relatively higher ammonia combustion efficiency and lower catalyst consumption[3]. The same system is used in the "Kima" plant and will be adopted in the other plants.

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3) Sauchelli, V., The Chemistry and Technology of Fertilizers, Reinhold Publishing Corporation, New York (1960), pages 16-21.

(c) The Fertilizer Plant at Helwan

13. A coke oven plant will be operated in 1963 for supplying coke to the adjacent Iron and Steel Works at Helwan using imported coal. The production cost of the coke, and hence of the steel, will depend to a great extent on the utilization of the coal by-products obtained in the coking plant, particularly the coke oven gas. Moreover the utilization of the blast furnace gas itself is also of considerable importance. It was, therefore, decided to utilise the coke oven gas, and if possible the blast furnace gas, in the production of nitrogen fertilizer.

The plant in its first stage was planned to have a capacity of 170 tons/day of ammonia and to produce calcium ammonium nitrate fertilizer.

(1) Selection of the Cracking Process of the Gases.

In the production of synthetic ammonia, approximately 70% of the total production cost is due to the cost of raw materials and energy. When planning to erect such a plant, it was therefore necessary to investigate all possible processes, with the object of choosing the most suitable one characterized by a minimum cost of gas and energy.

The utilization of the blast furnace gas would be attractive because its content of nitrogen will be available for being used and the $CO + H_2$ contents can already cover a portion of the hydrogen required for the ammonia synthesis .

The cracking of coke oven gas can be effected by one of the following processes :

a. An exclusively thermal and discontinuous process under normal pressure using steam and blast furnace gas. Cracking is effected in two aggregates at about 1400°C. Each aggregate consists of a gas cracker and a regenerator.

b. An exclusively thermal and continuous cracking under pressure (about 25 atm.) by means of air enriched with oxygen and without using blast furnace gas. Oxygen would be obtained in an air separation plant.

c. The catalytic and continuous cracking under pressure by pressure by means of oxygen and by using blast furnace gas.

As the required nitrogen is provided by the blast furnace gas, cracking is only effected with pure oxygen under a pressure of 25 atm. Owing to the use of a catalyst, cracking takes place at 900-1000°C instead of 1400°C.

d. The catalytic and continuous cracking under pressure by means of steam and air enriched with oxygen, and without using blast furnace gas. As in processes b., and c. oxygen is obtained from an air separation plant.

In all the above four processes the coke oven gas should be desulphurized before cracking.

It should be mentioned here that the process of low temperature fractionation of coke oven gas was excluded from the outset, since the available quantity of coke oven gas of about 360.000 m^3/day can only give about 200.000 m^3/day of hydrogen whilst approximately 360.000 m^3/day of hydrogen are required. Furthermore this process has a much higher energy consumption.

(ii) Advantages and Disadvantages of the Various Processes :

The main advantages and disadvantages of the four cracking processes were studied and can be summarised as follows :

Process a. has the advantage that the heat requirements can be covered by blast furnace gas, so that the more valuable coke oven gas must not be burnt, and maximum ammonia yield related to the coke oven gas could be obtained. Although an air separation plant is not required, yet this process proved to be less economic compared with processes . and d. as it requires too much steam and owing to the fact that it must be operated discontinuously in a very voluminous plant which has a relatively high investment cost. Also cracking under normal pressure indirectly causes increased compression cost compared with cracking under pressure, as the volume of the cracked gas is 1.8 times higher than that of the coke oven gas.

The cracking processes under pressure work continuously and need considerable smaller reaction space, hence their investment costs are lower.

Process b. has the disadvantage that it operates at a higher cracking temperature than both processes c.,and d., resulting in a relatively higher coke oven gas and oxygen consumption.

Process d. has the disadvantage that the heat demand is provided by the coke oven gas itself, thus raising its consumption correspondingly.

However, the most economic process under the prevailing local conditions could only be found by computation taking into consideration the gas and energy consumption figures and their prices as well as the investment and operation costs.

The computation was based upon the following local prices[4]:

Electric energy	0.006 LE/KWH
Steam	0.750 LE/ton
Coke oven gas	3.500 LE/1000m^3
Blast furnace gas	0.700 LE/1000m^3

Table 2 shows that process d. has the least equipment cost, and table 3 shows also that the same process is cheaper to operate than the other processes, and was accordingly chosen as the most suitable for the fertilizer plant of Helwan.

The Impact of the High Dam on the Fertilizer Industry

14. The generated power in the U.A.R. is expected to reach 6.4 billion KWH in 1965. After the construction of the High Dam, the power generated will increase to 16.5 billion KWH (about January 1968). Industry will then find ample and cheap supply of power. The construction of the Dam will also enable the conversion of the present basin irrigation into the perennial system, and an extension in the arable land area. Accordingly, it is estimated that an additional 300,000 tons of nitrogen fertilizers (15.5% N) and 60,000 tons of superphosphate would be needed by 1970 over and

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4) One Egyptian Pound (LE) is officially equivalent to 2.87 U.S. Dollars.

above the estimated needs at the end of the present five-year economic plan (i.e 1965). It is therefore contenplated that an extra nitrogen fertilizer plant, with an annual capactiy of about 500,000 tons calcium ammonium nitrate (20.5%N), and a triple superphosphate plant with an annual capacity of about 46,000 tons, would be erected in Aswan and Sebaiya respectively where both cheap power and rock phosphate are available.

15. The phosphoric acid for the manufacture of the triple superphosphate would be produced from the phosphate rock by the electric furnace method. (It would also be used to manufacture conlex sodium phosphates). The ammonia for the nitrogen fertilizer plant would be produced either from electrolytic hydrogen, or by conversion of the off-gases from the electric iron smelting furnaces of an adjacent iron and steel plant. It is estimated that the electrolytic method would consume annualy about 1350 million KWH where as the CO-conversion of furnace gas would consume only 160 million KWH. Preference would be given to one method or the other after a detailed study of the economic of each, and taking into consideration the amount of power available for industry, the number of electrochemical or electro-thermal projects to be inplemented, and their respective capacities.

Current Research and Development

16. Apart from about 30,000 tons of petroleum sulphur that will be produced from the coking plant, the U.A.R. inports all its requirements of sulphur or pyrite for the manufacture of sulphuric acid. On the other hand, ample quantities of by-product hydrochloric acid are now available from the caustic soda industry and more will be available from chlorination processes in the petrochemical complex project. Accordingly, applied research in the field of fertilizers in the U.A.R. is directed towards utilization of more hydrochloric acid and econonizing on the sulphuric acid consumption.

17. For example, pilot plant experiments are now being undertaken to produce ammonium sulphate by double decomposition between ammonium carbonate and the locally available gypsum. The object of these experiments is to produce the country's needs of ammonium sulphate, which are growing rapidly, by this method instead of producing ammonium sulphate by direct reaction of ammonia and sulphuric acid.

18. Again, dicalcium phosphate can be produced by the reaction between hydrochloric acid and rock phosphate to liberate phosphoric acid, and then by addition of the proper quantity of milk of lime to precepitate the dicalcium phosphate. Field experiments on certain crops are now being conducted with dicalcium phosphate as fertilizer and the results are promising.

19. To econonize on the use of sulphuric acid in the manufacture of superphosphate, experiments are being carried out to reduce considerably the carbonate content of the rock phosphate (normally between 8% and 14%) by treatment with hydrochloric acid before addition of the sulphuric acid.

Table 2

Estimated Equipment cost for the processes a. - d.

Investment cost in LE	a.	b.	c.	d.
Coke oven gas holder	60,000	60,000	60,000	60,000
Cracked gas holder	60,000	-	-	-
Dry desulphurization	61,100	65,500	63,800	65,500
Cracking plant	981,000	282,000	300,000	303,000
Air Separation plant	-	675,000	413,000	350,000
Oxygen compressors	-	-	84,000	-
Oxygen/air compressors	-	147,000	-	117,000
Coke oven gas compressors	-	205,000	191,000	203,000
Blast furnace gas compressors	-	-	157,000	-
Mixed gas compressors	352,000	-	-	-
Conversion plants	185,000	108,000	108,000	108,000
Equipment cost without erection (LE)	1,699,100	1,542,500	1,376,800	1,206,500

Table 1

Total Production of Nitrogen Fertilisers by 1965 in Metric Tons (Based on 15.5%N)

Plant and location	Type of Fertiliser	Capacity (tons 15.5%N)	Remarks
Kima Plant (Aswan)	calcium ammonium nitrate	650,000	already producing
Nasr Fertiliser and Chemicals plant (Suez)	calcium nitrate	250,000	already producing
	ammonium sulphate	135,000	production just starting
	calcium nitrate	260,000	scheduled for production in 1965
	calcium ammonium Nitrate	200,000	
Nasr Coke and Chemicals plant (Helwan, near Cairo)	calcium ammonium nitrate	260,000	scheduled for production in 1965
	urea	260,000	
Petrochemical Complex (Alexandria)	calcium nitrate	200,000	scheduled for production in 1965
	Total	2,215,000	

Table 3

Comparison of consumption figures and cost per day to be considered for processes a. - d.

Consumption figures	a.		b.		c.		d.	
	Quantity	Cost LE	Quantity	Cost LE	Quantity	Cost LE	Quantity	Cost LE
Electric energy / KWH	114,500	687	140,200	841	111,000	666	102,800	617
Steam / ton	160	120	-	-	-	-	-	-
Coke oven gas / m^3	199,000	696	301,000	1055	235,000	822	272,000	953
Blast furnace gas / m^3	377,000	262	73,000	51	215,000	150	56,000	39
Depreciation of equipment (10% annually, divided by 300 working days).		566		514		459		402
Total per day (LE)		2331		2461		2097		2011

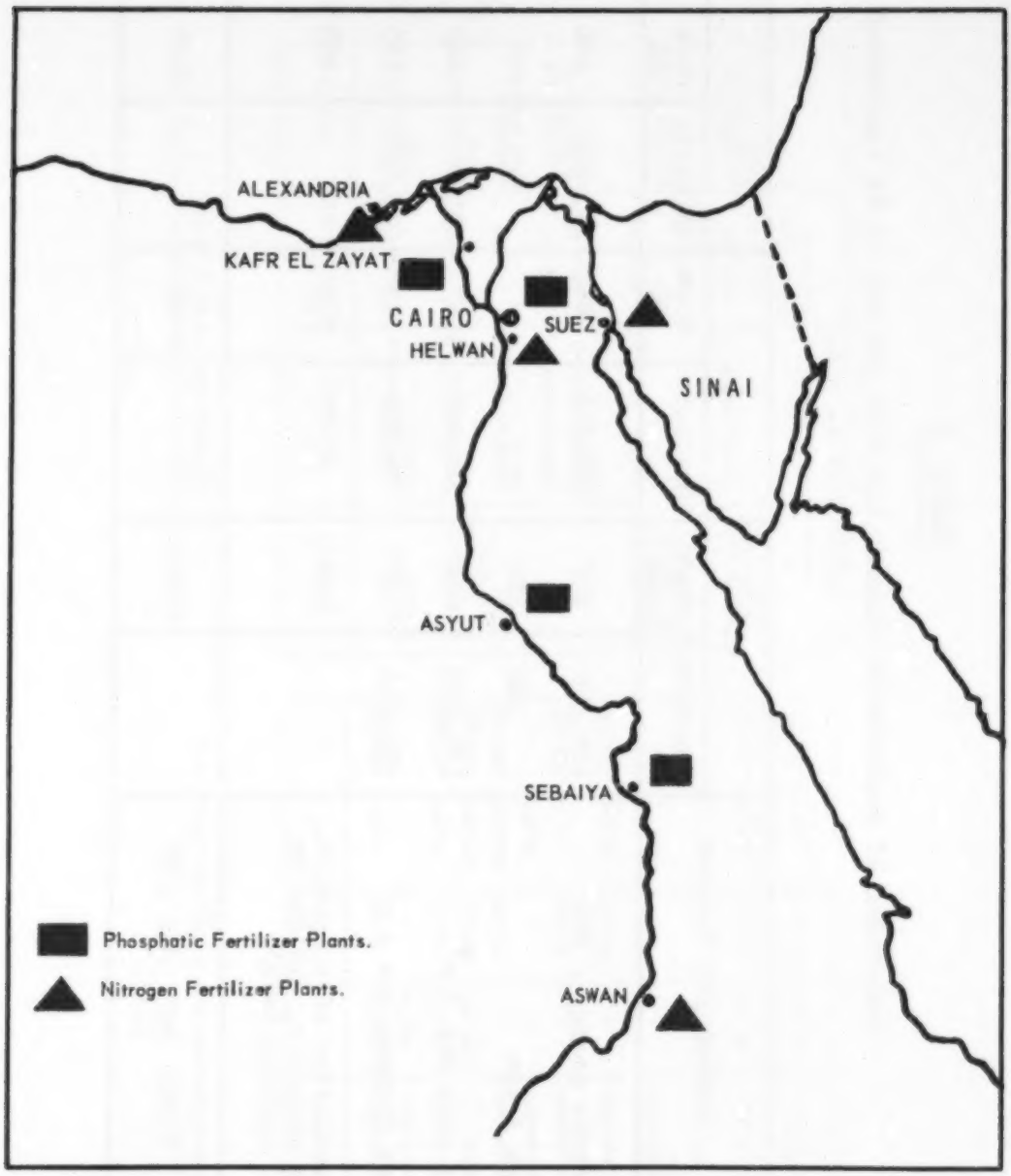

FIGURE 1

PRODUCTION OF FERTILIZERS IN THE U.A.R.

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